

CFD ANALYSIS OF MEMBRANE HELICAL COIL FOR OPTIMIZATION OF HIGH PRESSURE AND TEMPERATURE OF SYNGAS IN UNDERGROUND COAL MINES

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ABSTRACT

This research work investigates the flow field and the heat transfer characteristics of a Membrane Helical Coil Heat Exchanger for the cooling of syngas. Finite volume method based on FLUENT software practised and the RNG k-ε turbulence model was adopted for modelling flow turbulent. The distribution of the resistance, the distribution of the heat source, and the porosity rate introduced to ANSYS R18.0 by coupling the user-defined function. The variation of local heat transfer, the pressure drop, and the temperature distribution studied under the effects of the syngas components and the operating pressure, and the impact of the arrangement of the membrane on the heat transfer investigated. The results show that higher operating temperature and pressure can improve the heat transfer, however, brings more significant pressure and temperature drop. The components of the syngas significantly affect the heat transfer and the pressure drop. The arrangement of the membrane influences the fluid flow.

KEYWORDS: CFD, Syngas, Membrane Helical Coil Heat Exchanger, Heat transfer & Underground Coal Mines

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INTRODUCTION

The global concerns are that the syngas will raise in the underground mines. The continually rising syngas in underground mines are increasing the accident and diminishing the life of a worker who works in the underground mines, discover methods to minimise the disaster and survival of a worker who works in the underground mines. Membrane Helical Coil Heat Exchanger is a vital Heat Exchanger to reduce the high temperature and high pressure of syngas in underground mines.

It recognised that in Underground Coal Mines, the coal gasification with the heat recovery membrane helical coil heat exchanger shows high efficiency, so it is essential to understand the heat transfer characteristics of the heat exchangers.

The scope of this research work is to investigate the flow field and the heat transfer characteristics of the membrane helical coil heat exchanger for the cooling of syngas in underground coal mines by CFD simulation.

The membrane helical coil heat exchanger for the cooling of syngas in underground coal mines has two characteristics:

- The syngas includes different gas composition, and

- The syngas works at high pressure and temperature.

The calculated results were used to analyse the influence of syngas components, working pressure and the arrangement of the membrane on heat transfer.

DESIGN OF THE MEMBRANE HELICAL COIL HEAT EXCHANGER

Delineation of the Geometry

Set of standard types of heat exchangers are used in heat transfer applications, the membrane helical coil heat exchangers are still the most common type in use. They have more extensive heat transfer surface area-to-volume ratios than most of the common types of heat exchangers, and they are manufactured efficiently for a large variety of sizes and flow configurations. They are the cost-effective heat exchangers that can operate at high pressures, and their construction facilitates disassembly for periodic maintenance and cleaning.

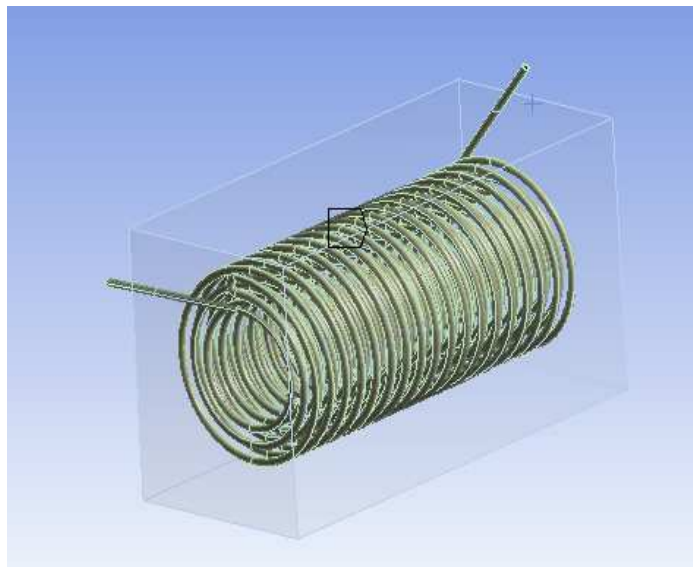


Figure 1: Geometry of Membrane Helical Coil Heat Exchanger

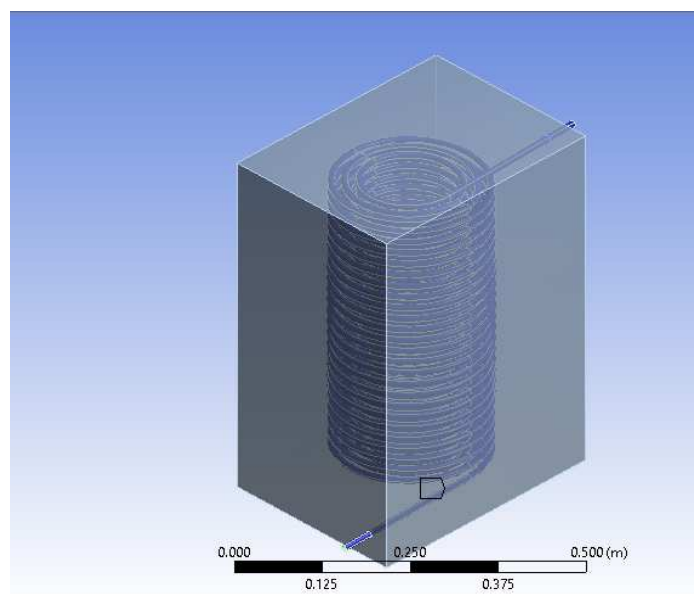


Figure 2: Geometry of Membrane Helical Coil Heat Exchanger

Figure 1 shows the zero and Figure 2 shows the geometries of the helical coil heat exchangers with three types of membrane arrangements called configuration 1, configuration 2 and configuration 3, respectively. The syngas passes through the tube side and the water falling on the tube. The U-tubes designed inside the tube which acts like a porous zone through which the syngas passes that absorbs required heat to decrease the temperature of the syngas. The syngas passes through the tube and gets cooled. The geometry parameters for membrane helical coil heat exchanger is given in Table 01.

Table 1: Geometry Parameter

Sr. No.	Parameter	Dimension
1.	Length of heat exchanger tube	0.5m
2.	Diameter of tube (d)	10mm
3.	Radial pitch between helical coil (p_1)	20 mm
4.	Thickness of tube (t)	2mm
5.	Inner Diameter of tube	8 mm
6.	Diameter of inner helical coil (D)	150mm

To simplify numerical simulation while still keep the essential characteristics of the process, the following assumptions are made:

- Tube-side fluid is of constant thermal properties;
- Heat transfer processes and Fluid flow are turbulent and in steady-state;
- Natural convection induced by the fluid density variation is neglected;
- Membrane Helical Coil Heat Exchanger is well-insulated hence the heat loss to the environment is ignored.

Mesh Generation

The 3D mesh system was established using the commercial code GAMBIT based on the 3D geometry. The computational domain meshes with unstructured tetrahedral elements. The meshes of the computational model for configuration1 are shown in Figure 03 and Figure 04. Grid independence tests are carried out to ensure that a near grid independent solution can be obtained. The commercial code ANSYS R18.0 is adopted to simulate the flow and heat transfer in the computational model.

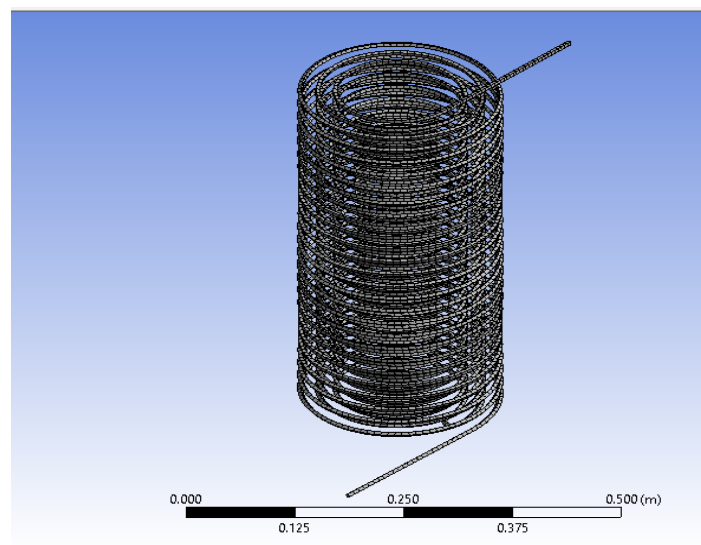


Figure 3: Meshing of Membrane Helical Coil Heat Exchanger

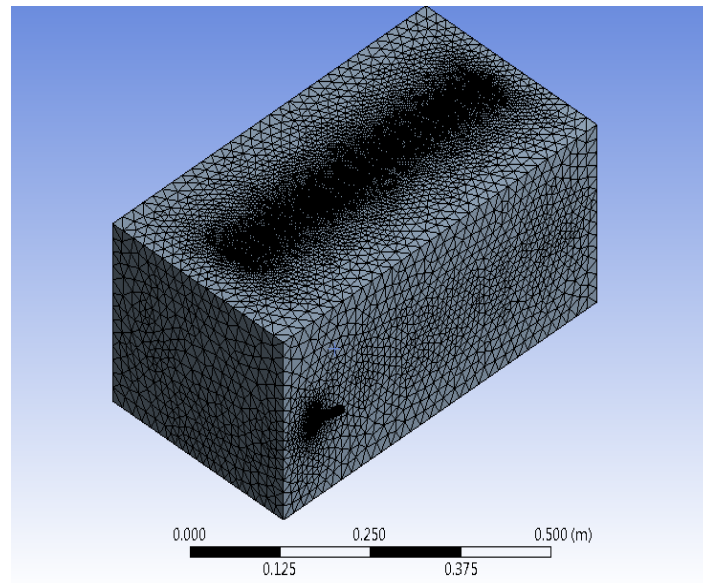


Figure 4: Meshing of Membrane Helical Coil Heat Exchanger

CFD Result

The CFD result of Membrane Helical Coil Heat Exchanger for

- The temperature of Gas Domain,
- The temperature of the Water Domain and
- The pressure of Gas Domain are obtained are as follows

The Temperature of the Syngas Domain

In a heat of syngas domain, we consider the following assumptions for getting the results of a temperature of syngas domain-

Input Data

- Fluid: Syngas and Water
- K-epsilon, realizable model, Scalable wall function
- Turbulence intensity- 5% & ratio- 10
- **Syngas Inlet**
Temperature- 325.3
- **Syngas Outlet**
Mass flow rate-0.167kg/s
- **Tube**
Convection-500w/m²k
Material-Copper Tube

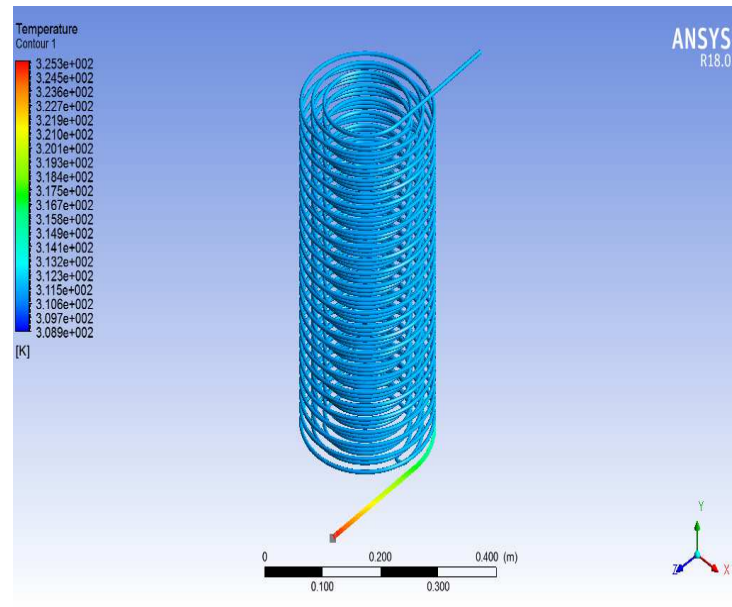


Figure 5: CFD Result of Membrane Helical Coil Heat Exchanger (Temperature of Syngas)

After completing the CFD simulations, we got the following results of Membrane Helical Coil Heat Exchanger in the temperature of syngas domain are as follows-

Inlet Temperature: 325.3 K

Outlet Temperature: 311.152 K

Temperature of Water Domain

In the temperature of water domain we consider the following assumptions for getting the results of the temperature of water domain-

Input Data

- **Fluid:** Syngas and Water
- K-epsilon, realizable model, Scalable wall function
- Turbulence intensity- 5% & ratio- 10
- Water Inlet
Velocity- 1m/s
Temperature-311
- **Water Outlet**
Mass flow rate-0.167kg/s
- **Tube**
Convection-500w/m²k
Material-Copper

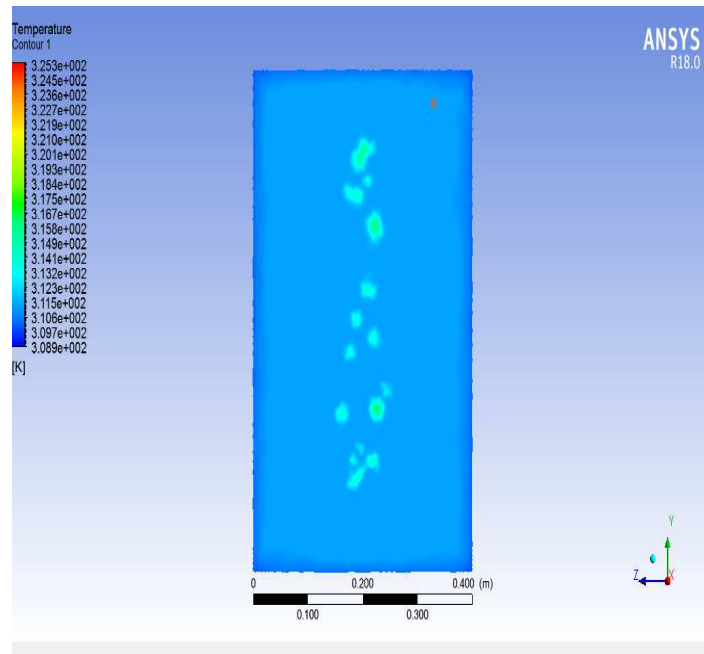


Figure 6: CFD Result of Membrane Helical Coil Heat Exchanger (Temperature of Water)

After completing the CFD simulations, we got the following results of Membrane Helical Coil Heat Exchanger in the temperature of the water domain are as follows-

Inlet Temperature: 311 K

Outlet Temperature: 316.32 K

Pressure of Syngas Domain

In Pressure of syngas domain we consider the following assumptions for getting the results of the pressure of syngas domain

Input Data

- **Fluid:** Syngas and Water
- K-epsilon, realizable model, Scalable wall function
- Turbulence intensity- 5% & ratio- 10
- **Gas Inlet**

Pressure- 245166Pa

- **Gas Outlet**

Mass flow rate-0.167kg/s

- **Tube**

Convection-500w/m²k

Material-Copper

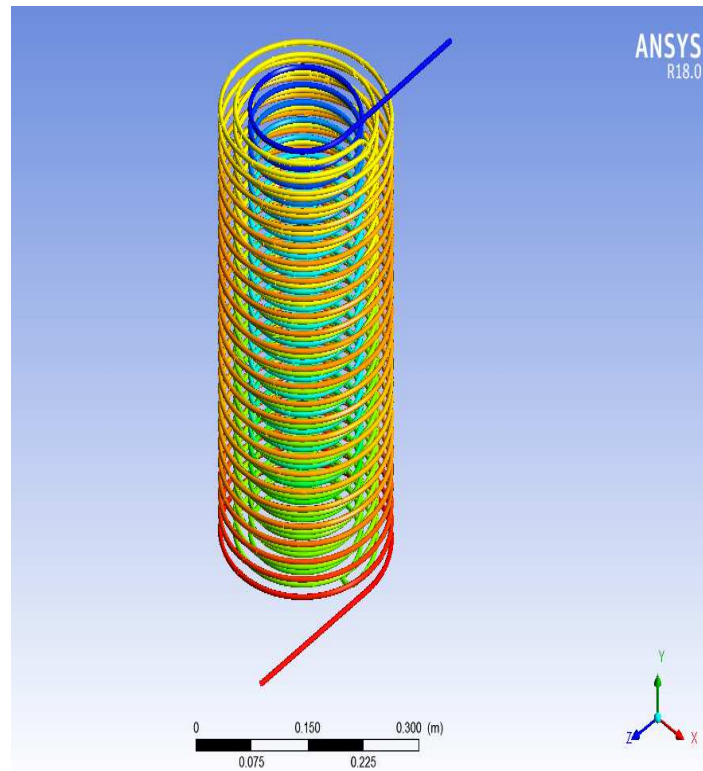


Figure 7: CFD Result of Membrane Helical Coil Heat Exchanger (Pressure of Syngas)

After completing the CFD simulations, we got the following results of Membrane Helical Coil Heat Exchanger in the pressure of syngas domain are as follows

Inlet pressure: 245053 Pa

Outlet Pressure: 94503 Pa

CONCLUSIONS

In this research paper, three-dimensional numerical simulations for Membrane Helical Coil Heat Exchanger with different membrane configuration and working condition are performed to reveal the effects of membrane configuration and working condition on the temperature drop and heat transfer characteristics.

The major findings are summarised as follows:

- Heat transfer analysis of a Membrane Helical Coil Heat Exchanger using CFD code ANSYS R18.0 has been present in this paper.
- Higher operation pressure and temperature of syngas from underground coal mines, however, brings more significant pressure drop because of the Membrane Helical Coil Heat Exchanger.
- The Membrane Helical Coil Heat Exchanger of the syngas significantly affect the pressure drop and the heat transfer.
- The heat transfer increases with higher H₂O percentage and lower H₂ percentage. The pressure drop increases with higher CO₂ percentage and lower H₂ percentage.

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